SMU Department of Physics
QUALIFYING EXAMINATION
Saturday , August 19, 2017
9:00AM to 11:00PM

Classical Mechanics

Two hours are permitted for the completion of this section of the examination. There are 5 problems included in this section, each is worth 20 points.   Apportion your time carefully.

Please write only on ONE SIDE of the paper, and DO NOT staple your sheets; they will be scanned in the auto-feeder. Clearly mark your initials on each page, and number each of your pages.

No reference materials or books are permitted. (If you believe there is a key piece of information or formula missing you may ask the proctor to check.)

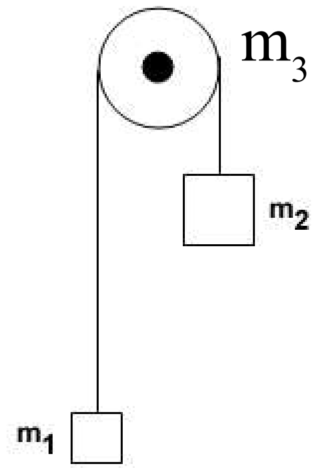
Simple calculators are permitted; cell phone calculators can NOT be used.

Questions should be directed to the proctor.

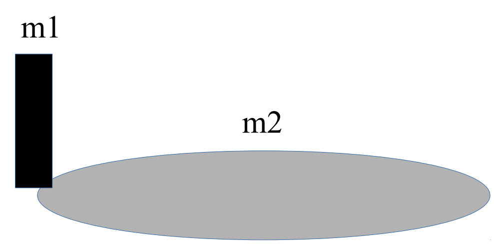
Good Luck!

Problem: 1

a) [10 points] An Atwood machine has masses m_1, m_2 and a frictionless <u>massive</u> pulley of mass m_3 in the shape of a disk ($I=m_3r^2/2$).
Write the equations of motion for the system, and compute the acceleration of the system in terms of the masses.



b) [10 points] A physics student (mass m_1=100kg) is on the edge of a merry-go-round of mass m_2=50Kg, radius r=10m, and $I=m_2r^2/2$. Initally, the merry-go-round is spinnning at w=10 RPM (revolutions per minute). The student then moves from the edge (r=10m) to r=5m. Find the final angular speed of the merry-go-round in both RPM (revolutions per minute) and rad/sec.



Problem: 2

[20 points]

a) [10 points] A pion π^+ at rest decays to a muon μ^+ and a neutrino ν, ($\pi^+ \rightarrow \mu^+ \nu$). In terms of the pion and muon masses (take the neutrino mass to be zero) $\{m_{\pi+}, m_\mu, m_\nu=0\}$, find the energy, momentum, and β=v/c of the muon.

b) [10 points]The pions are produced in the fixed-target interaction **pp→ πππpp** where a beam of protons hits a stationary target of protons, and produces a final state of 3 pions and 2 protons. Find the minimum energy of the proton beam for this reaction to occur.
[Assume pions of charge (+,-,0) are all the same mass (m_π).]
Express your answer in terms of the proton (m_p) and pion (m_π) masses.

Problem: 3

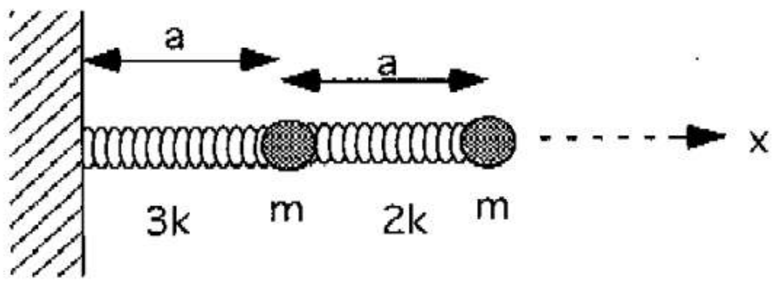
[20 points]

A bullet is fired straight up with an initial speed v_0. Assume quadratic air resistance with the drag constant c_2, show that when the bullet turns back and hits the ground, its speed is

$$\frac{v_0 v_t}{\sqrt{v_0^2 + v_t^2}} \qquad \text{with} \qquad v_t = \sqrt{mg/c_2} \text{ being the terminal speed.}$$

Assuming an air resistance force given by $\mathbf{-c_2\, v^2}$, where c_2 is the drag coefficient.

Problem: 4

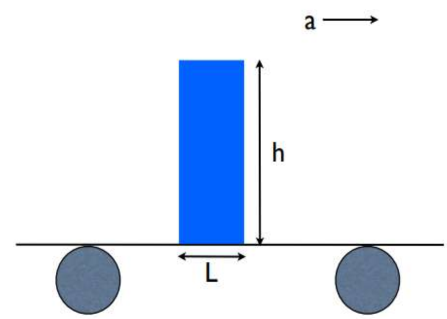


Two objects of mass m are attached to each other by a spring, and the left mass is also attached by a spring to a fixed wall. The springs are of equilibrium length a. The masses are on a frictionless surface and can only move along the x-axis. The left spring has spring constant 3k, and the right has 2k.

a) [10 points] Find the Lagrangian for this system.
b) [10 points] Find the normal modes and their frequencies.

Problem: 5

A truck carries a rectangular block of uniform mass density with height h, a square base with width L, and total mass M. The truck accelerates with constant acceleration "a". Assume the box does not slide.



(a) [6 points] In the frame of reference of the truck, draw all forces and pseudo forces acting on the block (and where they act) when the block just starts tipping over.

(b) [8 points] Calculate for what value of "a" the block starts to tip over.

(c) [4 points] If there is an additional small mass m glued to the center of the top of the block, for what value of "a" does the block start to tip over now?

(d) [2 point] Verify that your answer to (c) is smaller than what you found in part (b).